THE POSSIBLE EFFECT OF THE EXPANDING USE OF NATURAL GAS ON THE PRODUCTION OF COKE AND COAL CHEMICALS IN THE UNITED STATES

By J. A. DeCarlo and J. A. Corgan

* * * * * * * * * * Information Circular 7579

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
James Boyd, Director

Work on manuscript completed May 1950. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7579."

September 1950

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CONTENTS

	Page
Introduction	1
Acknowledgments	2
Summary	2
Development and importance of oven coke plants supplying city gas	3
Production and disposal of coke and coal-chemical materials by gas utility and merchant oven coke plants	4
Coke	4
Coke-oven gas	10
Coke-oven tar	13
Coke-oven crude light oil	13
Coke-oven ammonia	15

TABLES

1.	Coke plants that may be closed because of the introduction of natural gas or because of oven failure	3
2.	Salient statistics on coking operations of oven coke plants owned by gas utilities, merchant companies, and iron and steel works for selected years	5
3.	Gross value, f.o.b. plant, of all products reported by gas-utility coke plants for selected years	7
4.	Gross value, f.o.b. plant, of all products reported by merchant coke plants for selected years	8
5.	Sources of blast-furnace coke shipments in 1948	9
6.	Sources of foundry-coke shipments in 1948	10
7.	Sources of other industrial coke consumed in 1948	10
8.	Sources of coke-oven gas distributed by gas utilities, 1934, 1939, 1944, and 1948	11
9.	Comparative percentages of different kinds of manufactured gas distributed by gas utilities, 1934, 1939, 1944, and 1948	11

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TABLES (Cont'd.)

		Page
10.	Public utility gas sales, by type of gas, 1934, 1939, 1944, and 1948	12
11.	Coke-oven gas used for heating ovens, by kind of plants, in 1948	12
12.	Coke-oven tar sold to tar refineries, by kind of plants, 1934, 1939, 1944, and 1948	13
13.	Relative yields of light oil per ton of coal carbonized, by kind of plants, 1934, 1939, 1944, and 1948	14
14.	Coke-oven crude light oil produced and refined on premises, by kind of plants, 1934, 1939, 1944, and 1948, in gallons	14
15.	Production of benzol (all grades), by kind of plants, 1934, 1939, 1944, and 1948	15
16.	Production of coke-oven ammonia liquor, by kind of plants, 1934, 1939, 1944, and 1948	15
17.	Sources of ammonium sulfate produced in the United States, 1934, 1939, 1948, and 1949	16
18.	Production of coke-oven ammonium sulfate, by kind of plants, 1934, 1939, 1944, and 1948	16

ILLUSTRATIONS

Fig.		Follows page
1.	Comparative percentages of gross value contributed by each primary product of gas-utility coke plants	4
2.	Comparative percentages of gross value contributed by each primary product of merchant coke plants.	4

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INTRODUCTION

Development of high-pressure transcontinental gas-transmission systems in the United States has made natural gas available to markets many miles distant from producing fields. Increasing demand for natural gas and the greater availability of steel are accelerating the construction of new pipe lines, and natural-gas service is extending rapidly into many new areas. In some localities coke-oven gas has already been displaced, and contemplated new pipe lines will extend to other areas where coke-oven gas is currently distributed by city gas utilities. To determine what effect the introduction of natural gas into certain areas might have on the production of oven coke, coke-oven gas, and coal chemicals, the Bureau of Mines conducted a survey of all oven coke plants operated by gas utilities, commercial or merchant companies, and merchant pig-iron producers. This study did not include coke plants integrated with steel plants nor coal-gas plants operating gas retorts. A form letter was mailed to the coke-plant operators requesting the following information:

1. If natural gas is already in your area or is expected to be introduced within the next five years, will coke-oven and/or water gas be mixed with the natural gas, thus insuring continued operation of your coke-oven plant?

2. If your coke-oven gas is not to be distributed as city gas, will you continue to operate the coke plant to produce coke and coal chemicals, or will the plant be closed?

3. If you cannot sell city gas, is there any other market for your gas which will assure continued operation of the coke-oven plant?

4. If you plan to close your coke plant, can you give us the approximate date of such closing?

5. If the plant is closed, will it be dismantled or left in a stand-by condition?

Replies were received from all of the companies canvassed and, although some companies could not at this time make a definite statement regarding the effect that increasing supplies of natural gas might have on their coking operations, the information submitted was considered adequate to make a general appraisal of the problem.

3332

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ACKNOWLEDGMENTS

The Bureau of Mines appreciates the cooperation of all the companies circularized in this survey and the assistance rendered by members of the National Security Resources Board is gratefully acknowledged. Valuable statistical assistance was given by Maxine M. Otero, of the Bureau of Mines.

SUMMARY

The coke plants most likely to be affected by the introduction of natural gas into an area are those classified by the Bureau of Mines as gas utilities and merchant operations. The quantities of coke and coal chemicals produced by these plants are substantial, although there has been a steady decline in proportion of coal products produced by them to the national total. In 1948, the output of coke from these plants totaled 13,332,499 net tons, or nearly 20 percent of the total oven coke produced in the United States. All of the plants that contributed to this tonnage were canvassed to determine the possible effect that the substitution of natural gas for coke-oven gas might have on their continued operations. The replies were analyzed, and the result indicated that five plants and one battery at another, which operated in 1948, expect to discontinue operations as soon as natural gas is introduced. These plants, which operated 310 ovens with an annual coke capacity of 1,298,400 net tons, produced 1,285,371 tons of coke in 1948. Thus, about 10 percent of the annual coke production of the merchant and gas utility companies and 2 percent of the total United States annual coke capacity is expected to be lost because of the substitution of natural gas for coke-oven gas within the next 5 years. There is a possibility, however, that several of the larger plants now operated by gas utility companies may be sold to other interests, and that the coke plants will continue to operate.

In addition to the above, four coke-plant operators reported that one of the most important problems confronting them that will have a bearing on their continued operation is that of oven replacement. The coke ovens at such plants are fairly well-depreciated, and although their remaining economic life is unknown it is estimated that the ovens will be retired in less than 10 years. The companies in this category, having a total of 271 ovens with an annual coke capacity of 1,219,000 net tons, produced a total of 1,228,721 tons of coke in 1948, an amount slightly greater than capacity. The operators of these plants where the economic life of the ovens appears to be limited reported that they cannot justify the replacement of ovens because, even if mixed gas is distributed, the natural-gas equivalent price of coke-oven gas does not compensate for the cost of producing coke-oven gas. It was pointed out, also, that under present economic conditions difficulty is experienced in making limited repairs, because maintenance, rehabilitation, and construction costs are so high. It is possible, therefore, based on the reports received, that within the next 10 years a total of 592 coke ovens with a capacity of 2,547,200 net tons and a production in 1948 of 2,541,088 tons, may cease operations because of the substitution of natural gas for coke-oven gas. This group of ovens constituted 3 percent of the oven-coke capacity, and they produced nearly 4 percent of the total coke output in 1948.

In addition, several coke plants that produce pig iron for merchant sale only, as well as several merchant coke plants, stated that loss of their present

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city gas contracts may force them to curtail their current rate of coke and coal-chemicals production, but such an eventuality would not force closing the plants.

The ovens affected by the introduction of natural gas supply only a small amount of coke for blast-furnace use, hence their closing is not expected to have any great effect on blast-furnace operations; however, because the affected plants are widely scattered and in some instances located great distances from other sources of coke supply, a large number of iron foundries and small industrials purchasing coke from these plants will have a disruption of supply. The losses of chemical raw materials (crude tar, ammonia, and light oil), percentagewise, from these plants are not large and under normal economic conditions should not have any great effect on the chemical industry. However, in times of emergency the loss of coal chemicals from these plants could be more serious.

TABLE 1. - Coke plants that may be closed because of the introduction of natural gas or because of oven failure

	Group I[a/]	Group II[b/]	Total
Number of plants	5	5	10
Number of ovens	310	282	592
Annual coke capacity.....net tons	1,298,400	1,248,800	2,547,200
Production 1948:			
Coke.....do.	1,285,371	1,255,717	2,541,088
Gas.....M cu. ft.	18,487,417	17,208,512	35,695,929
Tar.....gal.	13,392,879	13,194,338	26,587,217
Ammonia.....net tons	15,212	9,839	25,051
Light oil.....gal.	3,298,659	4,064,745	7,363,404

a/ Operations that expect to close within the next 5 years because of the substitution of natural gas for coke-oven gas.

b/ Operations that may shut down within the next 10 years because of oven failures and the high cost of rebuilding the ovens, making it economically impossible to compete with natural gas.

DEVELOPMENT AND IMPORTANCE OF OVEN COKE PLANTS SUPPLYING CITY GAS

High-temperature slot-type coke ovens have supplied a large percentage of the manufactured gas distributed by gas utilities through city mains for many years. The first oven coke plant built specifically to supply city gas was constructed by the New England Gas & Coke Co. at Everett, Mass., in 1898 and consisted of 8 batteries of 50 ovens each of the Otto-Hoffman type. In 1903 the second coke plant built to supply city gas was erected by the South Jersey Gas, Electric, & Traction Co. at Camden, N. J., and totaled 100 Otto-Hoffman ovens. Gas utilities continued to build coke plants in the ensuing years and by 1918 operated 9 of a total of 60 oven-coke plants. The trend continued upward until the middle 1930's, reaching a peak of 23 utility plants in 1934. Since that year, extension of natural-gas pipe lines has placed natural gas in markets formerly served by coke-oven gas, and as a consequence, a number of these plants have been closed and dismantled, until by the end of 1948 only 13 plants classified by the Bureau of Mines as gas utilities were in operation.

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With the expansion of coke-making facilities in recent years, larger quantities of surplus coke-oven gas have been available from merchant companies and iron and steel producers. This has been purchased by gas utilities for distribution through city mains to residential, commercial, and industrial consumers. In 1948 there were 18 merchant coke plants active, of which 10 sold coke-oven gas to utilities. In addition, gas utilities purchased coke-oven gas from 23 oven-coke plants associated with the iron and steel industry. Salient statistics, by groups of plants, on their coking operations for selected years are shown in table 2.

PRODUCTION AND DISPOSAL OF COKE AND COAL-CHEMICAL MATERIALS BY GAS UTILITY AND MERCHANT OVEN COKE PLANTS

The carbonization of coal in slot-type coke ovens owned and operated by merchant and gas-utility plants is not economically profitable unless the principal product, coke, and the secondary products, gas, tar, crude light oil, and ammonia are produced efficiently and sold under favorable conditions. The production of any one product is almost invariably accompanied by the production of all of the others, and, therefore, a properly balanced market for coke, gas, tar, and other products is an important economic factor in the production of coke and coal chemicals by gas-utility and merchant coke plants.

The gross value, f.o.b. plant, of all products reported by merchant and gas-utility plants for 1934, 1939, 1944, and 1948 are shown in tables 3 and 4. Figures 1 and 2 show, according to plant classification, the importance of each of the five primary products as sources of revenue.

The quantities and relative percentages of the five primary products supplied by the merchant and gas-utility plants in recent years are summarized in the following discussion and compilations.

Coke

Coke is the most important product of coal carbonization if judged by weight, heat content, or dollar value. The importance of coke to merchant and gas-utility operations is clearly illustrated in figures 1 and 2, which show that the value of coke, depending on market conditions, represents from 47 to 73 percent of the total gross value of all products.

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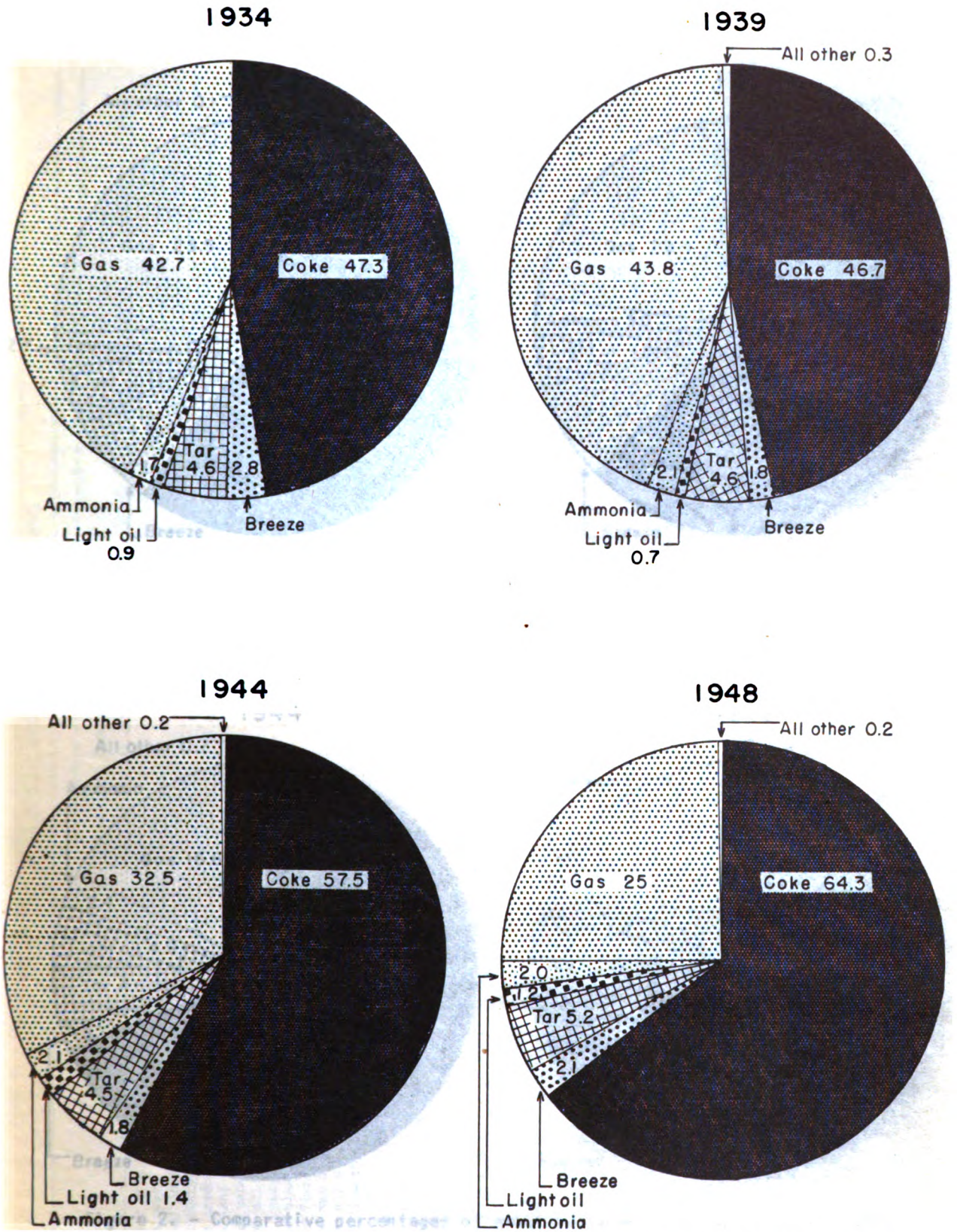

Figure 1. - Comparative percentages of gross value contributed by each primary product of gas utility coke plants.

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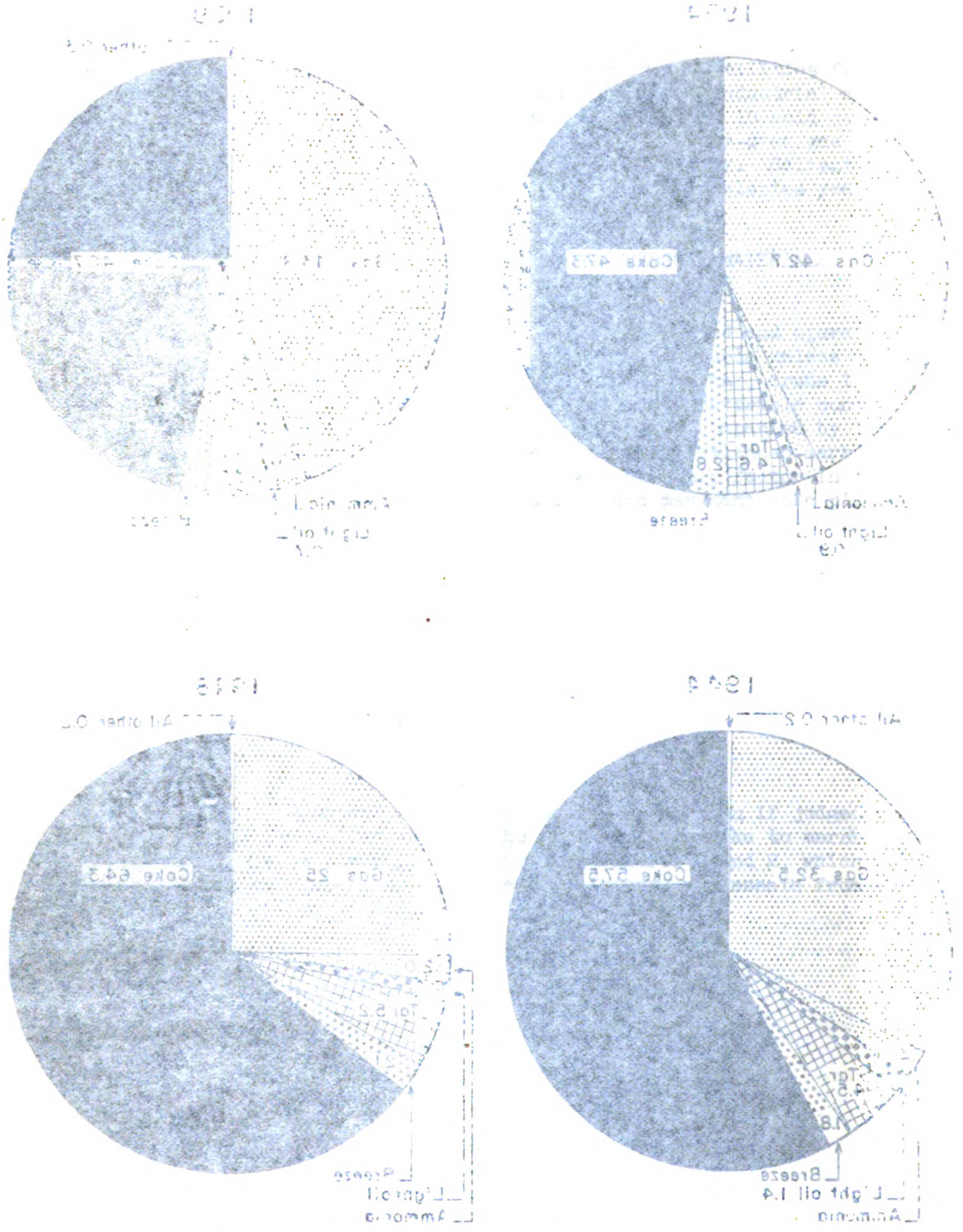

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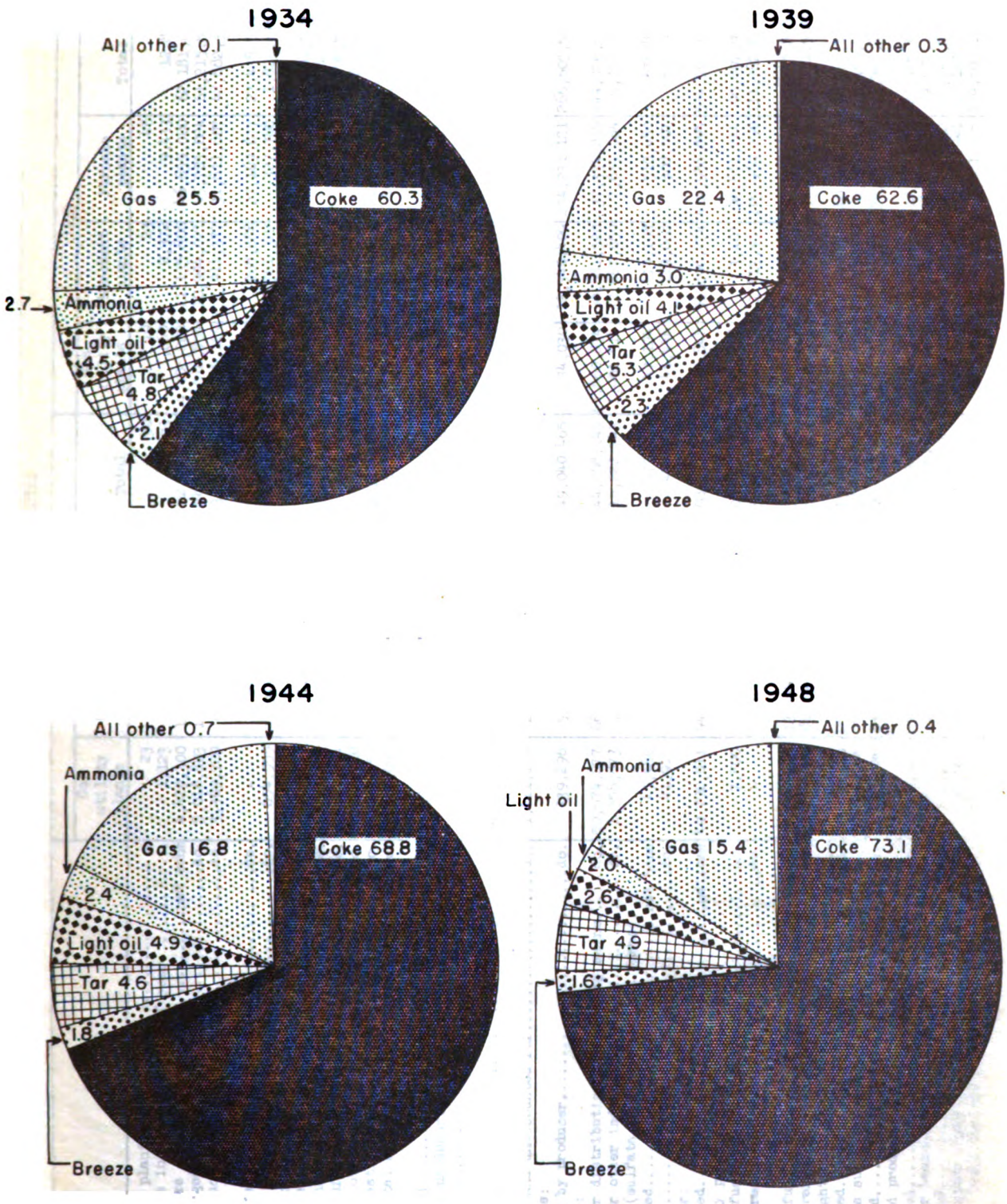

Figure 2. - Comparative percentages of gross value contributed by each primary product of merchant coke plants.

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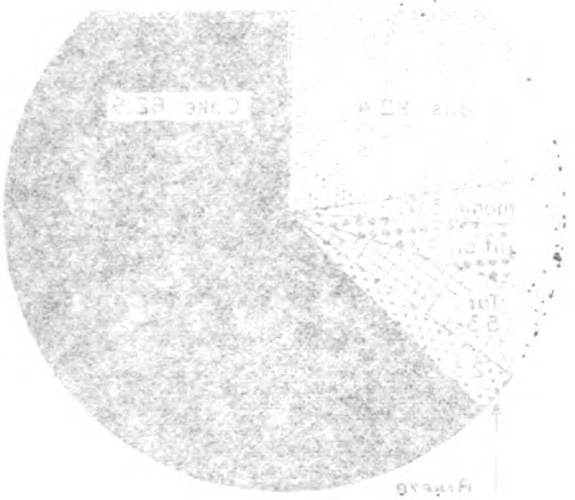

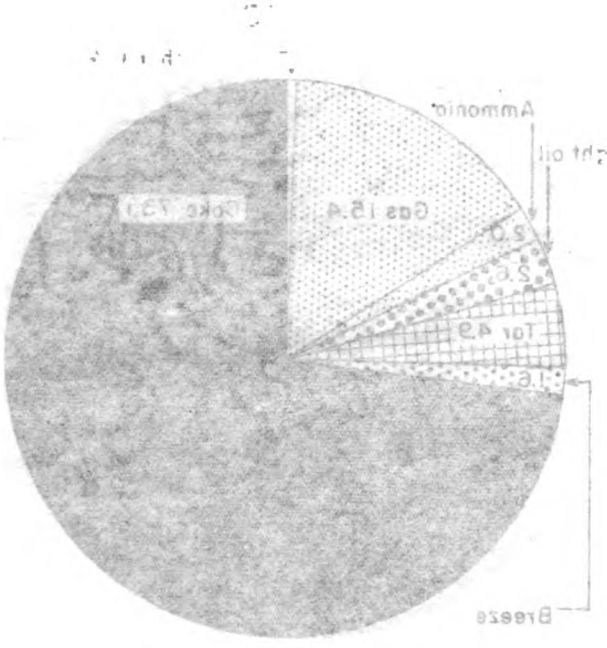

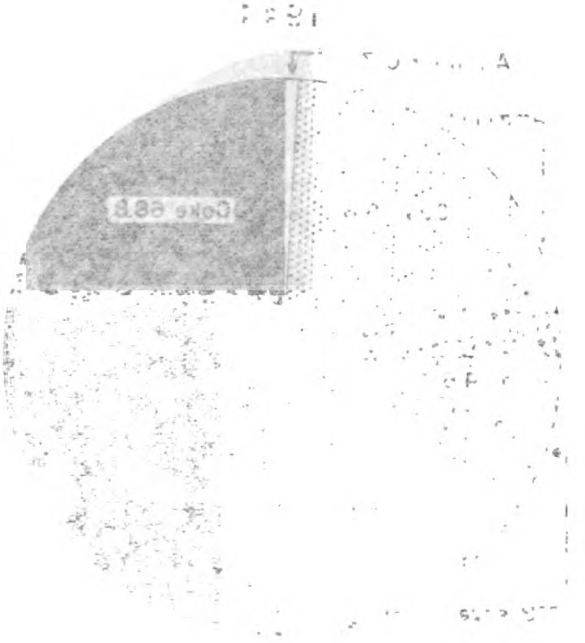

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TABLE 7. - Salient statistics on coking operations of oven coke plants owned by gas utilities, merchant companies, and iron and steel works for selected years

	1934				1939			
	Gas utility plants	Merchant plants	Furnace plants	Total	Gas utility plants	Merchant plants	Furnace plants	Total
Number of plants in existence	23	21	46	90	19	23	46	88
Coke ovens in existence, end of year	1,123	2,484	9,356	12,963	1,060	2,372	9,433	12,865
Annual coke capacity.....net tons	4,429,300	11,163,100	47,164,600	62,757,000	4,406,200	11,135,800	46,639,000	62,181,000
Coal charged.....do.	5,016,803	11,447,238	27,878,957	44,342,998	4,518,854	10,994,021	45,703,024	61,215,899
Coke produced.....do.	3,369,729	8,181,232	19,241,850	30,792,811	3,159,129	7,911,377	31,811,807	42,882,313
Coke used by producer:								
For metallurgical purposes.....do.	-	82,069	13,754,566	13,836,635	-	268,888	27,169,677	27,438,565
For all other purposes.....do.	654,555	519,560	302,385	1,476,500	736,561	761,327	327,788	1,825,676
Coke sold:								
For blast furnace use.....do.	114,110	511,923	1,394,419	2,020,452	28,918	709,118	2,463,619	3,201,655
For foundry use.....do.	89,702	652,371	335,143	1,077,216	174,811	969,467	338,568	1,482,846
For manufacture of water gas.....do.	40,214	535,920	11,304	587,438	15,503	459,312	32,042	506,857
For all other industrial use.....do.	262,610	375,632	347,803	986,045	463,084	1,009,563	404,759	1,877,406
For domestic use.....do.	2,039,459	5,198,837	2,935,818	10,174,114	1,829,309	4,153,667	1,566,961	7,549,937
Total sold.....do.	2,546,095	7,274,683	5,024,487	14,845,265	2,511,625	7,301,127	4,805,949	14,618,701
Breeze:								
Produced.....do.	391,231	765,173	1,574,237	2,730,641	256,356	691,590	2,406,428	3,354,374
Used by producer.....do.	345,849	409,405	1,341,946	2,097,200	233,277	510,045	2,120,312	2,863,634
Sold.....do.	48,413	367,251	260,303	675,967	41,789	213,019	257,567	512,375
Gas:								
Produced.....M cubic feet	59,228,634	127,343,865	307,009,252	493,581,751	52,744,085	119,332,993	503,066,123	675,143,201
Used in heating ovens.....do.	5,645,009	41,932,577	128,290,937	175,868,523	3,477,878	32,526,460	196,859,718	232,864,056
Wasted and unaccounted for.....do.	1,211,179	2,465,974	4,464,718	8,141,871	469,829	1,116,945	6,981,081	8,567,855
Surplus:								
Used by producer.....do.	139,296	9,499,047	139,402,122	149,040,465	34,030	12,340,409	254,231,121	266,605,560
Sold:								
For distribution through city mains.....do.	50,674,277	66,004,924	27,628,948	144,308,149	46,860,834	60,681,520	37,334,219	144,876,573
For other industrial use.....do.	1,558,873	7,441,343	7,222,527	16,222,743	1,901,514	12,667,659	7,659,984	22,229,157
Ammonia (sulfate equivalent of all forms):								
Produced.....net tons	45,480	121,718	312,712	479,910	47,124	119,198	510,480	676,802
Sold.....do.	41,916	116,261	313,850	472,027	45,446	119,068	508,507	673,021
Crude tar:								
Produced.....gallons	49,790,011	94,212,032	264,708,271	408,710,314	44,520,848	91,896,474	417,988,894	554,406,216
Used by producer:								
For fuel and other purposes.....do.	7,500	262,705	108,650,817	108,921,022	23,308	3,401	90,871,244	90,897,953
For refining.....do.	-	577,401	35,766,368	36,343,769	-	1,813,553	109,969,290	111,782,843
Sold:								
For fuel.....do.	971,414	13,214,164	23,112,242	37,297,820	3,788,359	5,947,621	56,406,900	66,142,880
For refining.....do.	51,683,000	81,994,534	102,788,385	236,465,919	40,257,134	82,110,109	156,024,259	278,391,502
Crude light oil:								
Produced.....do.	4,106,510	25,669,724	85,918,514	115,694,748	3,684,136	26,595,829	140,683,234	170,963,199
Sold as such.....do.	3,102,425	7,336,564	1,209,737	11,648,726	2,858,355	4,953,915	1,571,637	9,383,907
Refined.....do.	1,013,606	23,238,011	83,967,847	108,219,464	708,733	25,196,758	138,041,676	163,947,167
Derived products produced:								
Benzol.....do.	369,345	5,855,928	15,465,606	21,690,879	80,814	6,524,234	18,700,666	25,305,714
Motor benzol.....do.	136,655	8,586,644	41,323,311	50,046,610	201,489	8,539,744	70,865,917	79,607,150
Toluol.....do.	154,129	3,219,946	9,907,719	13,281,794	129,890	3,879,308	15,758,002	19,767,200
All other light-oil derivatives.....do.	138,084	1,938,883	7,473,889	9,550,856	174,835	2,793,351	12,156,941	15,125,127
Total derived products.....do.	798,213	19,601,401	74,170,525	94,570,139	587,028	21,736,637	117,481,526	139,805,191

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TABLE 2. - Salient statistics on coking operations of oven coke plants owned by gas utilities, merchant companies, and iron and steel works for selected years (Cont'd.)

	1944				1948			
	Gas utility plants	Merchant plants	Furnace plants	Total	Gas utility plants	Merchant plants	Furnace plants	Total
Number of plants in existence	15	21	53	89	13	18	55	86
Coke ovens in existence, end of year	953	2,391	11,236	14,580	980	2,003	12,156	15,139
Annual coke capacity.....net tons	4,081,600	11,263,100	56,985,500	72,330,200	4,226,900	9,973,000	60,300,000	74,499,900
Coal charged.....do.	5,546,852	14,012,259	74,878,776	94,437,887	5,581,807	13,090,661	78,567,850	97,240,318
Coke produced.....do.	3,941,261	10,203,690	52,919,844	67,064,795	3,881,973	9,450,526	54,951,858	68,284,357
Coke used by producer:								
For metallurgical purposes.....do.	-	411	37,800,394	37,800,805	-	592	39,086,215	39,086,807
For all other purposes.....do.	1,272,034	1,453,885	161,979	2,887,898	1,450,087	985,198	290,238	2,725,523
Coke sold:								
For blast furnace use.....do.	205,850	1,690,953	12,020,052	13,916,855	547,698	1,620,734	12,789,774	14,958,206
For foundry use.....do.	417,924	1,274,433	541,451	2,233,808	719,233	1,858,544	584,460	3,162,237
For manufacture of water gas.....do.	55,067	1,344,015	36,658	1,435,740	98,959	2,068,562	64,268	2,231,789
For all other industrial use.....do.	205,393	1,114,550	681,755	2,001,698	245,838	1,071,985	776,566	2,094,389
For domestic use.....do.	1,699,668	3,230,497	1,513,164	6,443,329	836,756	1,850,371	711,569	3,398,696
Total sold.....do.	2,583,902	8,654,448	14,793,080	26,031,430	2,448,484	8,470,196	14,926,637	25,845,317
Breeze:								
Produced.....do.	348,455	722,336	3,894,273	4,965,064	405,246	709,933	4,650,397	5,765,576
Used by producer.....do.	311,952	541,720	3,229,428	4,083,100	386,675	551,718	3,607,483	4,545,876
Sold.....do.	28,973	168,669	820,505	1,018,147	20,313	170,416	930,882	1,121,611
Gas:								
Produced.....M cubic feet	61,446,142	147,100,244	800,253,540	1,008,799,926	60,987,060	130,934,123	802,931,443	994,852,626
Used in heating ovens.....do.	3,315,936	44,792,609	324,915,576	373,024,121	4,603,726	40,482,992	325,569,098	370,655,816
Wasted and unaccounted for.....do.	531,462	2,159,919	11,922,813	14,614,194	632,775	1,328,125	14,425,075	16,385,975
Surplus gas:								
Used by producer.....do.	12,800	19,900,870	395,130,824	415,044,494	205,665	13,597,782	388,806,570	402,610,017
Sold:								
For distribution through city mains.....do.	53,460,225	63,153,726	53,699,954	170,313,905	53,453,433	57,284,593	58,609,888	169,347,914
For other industrial use.....do.	4,125,719	17,093,120	14,584,373	35,803,212	2,091,461	18,240,631	15,520,812	35,852,904
Ammonia (sulfate equivalent of all forms):								
Produced.....net tons	50,457	135,002	759,444	944,903	44,361	118,453	766,879	929,693
Sold.....do.	48,963	140,071	707,945	896,979	44,888	125,244	755,932	926,064
Crude tar:								
Produced.....gallons	48,662,221	111,571,613	607,573,337	767,807,171	45,819,897	96,962,707	595,972,502	738,755,106
Used by producer:								
For fuel and other purposes.....do.	6,539	652,367	162,105,528	162,764,434	3,268	-	140,059,732	140,063,000
For refining.....do.	-	1,963,733	198,606,351	200,570,084	-	2,097,723	192,136,806	194,234,529
Sold:								
For fuel.....do.	-	-	15,851,012	15,851,012	452,433	-	34,224,944	34,677,377
For refining.....do.	48,782,568	108,939,425	233,616,442	391,338,435	45,126,767	94,077,524	228,525,812	367,730,103
Crude light oil:								
Produced.....do.	8,721,650	38,180,257	220,960,077	267,861,984	8,217,029	26,688,265	221,183,771	256,089,065
Sold as such.....do.	4,965,049	5,966,492	9,843,558	20,775,099	2,848,114	6,422,789	8,371,858	17,642,761
Refined.....do.	4,109,503	41,962,551	211,972,478	258,044,532	5,295,571	24,623,300	213,037,345	242,956,216
Derived products produced:								
Benzol.....do.	595,374	23,243,204	123,071,305	146,909,883	1,223,114	13,592,735	135,183,033	149,998,882
Motor benzol.....do.	1,860,738	2,506,308	14,189,509	18,556,555	1,694,766	1,326,951	5,992,619	9,014,336
Toluol.....do.	701,888	6,731,158	26,095,186	33,528,232	582,423	3,292,713	24,573,123	28,448,259
All other light-oil derivatives.....do.	714,694	4,226,878	18,500,441	23,442,013	1,224,854	3,642,463	16,222,289	21,089,606
Total derived products.....do.	3,872,694	36,707,548	181,856,441	222,436,683	4,725,157	21,854,862	181,971,064	208,551,083

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TABLE 3. - Gross value, f.o.b. plant, of all products reported by gas-utility coke plants for selected years

	1934				1939			
	Total value (dollars)	Percent of total value	Value per ton of coke produced	Value per MCF of surplus gas	Total value (dollars)	Percent of total value	Value per ton of coke produced	Value per MCF of surplus gas
Coke:								
Used by producer	$4,157,040	9.50	$1.24	$0.079	$4,642,504	10.46	$1.47	$0.095
Sold:								
For blast furnace use	726,844	1.66	.22	.014	158,224	.36	.05	.003
For foundry use	679,543	1.56	.20	.013	1,517,709	3.41	.48	.031
For other industrial use	2,002,180	4.58	.59	.038	2,928,449	6.59	.93	.060
For domestic use	13,102,653	29.95	3.89	.250	11,506,160	25.90	3.64	.236
Total coke	20,668,260	47.25	6.14	.394	20,753,046	46.72	6.57	.425
Breeze:								
Used by producer	1,084,309	2.48	.32	.021	696,332	1.57	.22	.014
Sold	126,088	.29	.04	.002	104,914	.23	.03	.002
Total breeze	1,210,397	2.77	.36	.023	801,246	1.80	.25	.016
Tar and its derivatives sold	2,027,506	4.63	.60	.039	2,040,637	4.59	.64	.042
Light oil and its derivatives sold	408,864	.94	.12	.008	306,220	.68	.10	.007
Ammonia sold	753,681	1.72	.22	.015	933,132	2.10	.29	.019
Surplus gas:								
Used by producer	25,338	.06	.01	-	7,831	.02	-	-
Sold as city gas	18,177,279	41.56	5.39	.347	18,866,740	42.46	5.97	.387
Sold for industrial use	462,405	1.05	.14	.009	609,000	1.37	.20	.012
Total gas	18,665,022	42.67	5.54	.356	19,483,571	43.85	6.17	.399
All other products sold, including naphthalene	8,983	.02	-	-	114,690	.26	.04	.003
Total gross value, all products	43,742,713	100.00	12.98	.835	44,432,542	100.00	14.06	.911
Cost of coal	23,453,074	53.62	6.96	.448	22,423,699	50.47	7.10	.460

	1944				1948			
Coke:								
Used by producer	$8,818,105	15.17	$2.24	$0.153	$17,943,557	20.17	$4.62	$0.322
Sold:								
For blast furnace use	1,763,817	3.03	.45	.031	8,651,523	9.73	2.23	.155
For foundry use	4,870,170	8.38	1.24	.084	13,883,905	15.61	3.57	.249
For other industrial use	2,333,194	4.01	.59	.040	5,234,844	5.89	1.35	.094
For domestic use	15,645,182	26.91	3.97	.272	11,475,855	12.90	2.96	.206
Total coke	33,430,468	57.50	8.49	.580	57,189,684	64.30	14.73	1.026
Breeze:								
Used by producer	986,175	1.70	.25	.017	1,819,865	2.05	.47	.033
Sold	85,778	.14	.02	.002	83,002	.09	.02	.001
Total breeze	1,071,953	1.84	.27	.019	1,902,867	2.14	.49	.034
Tar and its derivatives sold	2,616,965	4.50	.67	.044	4,654,863	5.23	1.20	.083
Light oil and its derivatives sold	845,971	1.46	.21	.015	1,050,133	1.18	.27	.019
Ammonia sold	1,197,041	2.06	.30	.021	1,778,010	2.00	.46	.032
Surplus gas:								
Used by producer	4,034	.01	-	-	32,979	.04	.01	.001
Sold as city gas	17,485,326	30.08	4.44	.304	21,215,169	23.85	5.47	.380
Sold for industrial use	1,391,594	2.39	.35	.024	950,719	1.07	.24	.017
Total gas	18,880,954	32.48	4.79	.328	22,198,867	24.96	5.72	.398
All other products sold, including naphthalene	90,397	.16	.02	.002	165,318	.19	.04	.003
Total gross value, all products	58,133,749	100.00	14.75	1.009	88,939,742	100.00	22.91	1.595
Cost of coal	34,225,442	58.87	8.68	.594	53,382,920	60.02	13.75	.958

3682

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TABLE 4. - Gross value, f.o.b. plant, of all products reported by merchant coke plants for selected years

	1934				1939			
	Total value (dollars)	Percent of total value	Value per ton of coke produced	Value per MCF of surplus gas	Total value (dollars)	Percent of total value	Value per ton of coke produced	Value per MCF of surplus gas
Coke:								
Used by producer	$3,061,369	3.89	$0.38	$0.037	$5,168,269	6.36	$0.65	$0.060
Sold:								
For blast furnace use	2,811,847	3.58	.34	.034	3,241,227	3.99	.41	.038
For foundry use	4,454,548	5.67	.55	.054	8,221,112	10.12	1.04	.096
For other industrial use	5,224,932	6.64	.64	.063	8,533,316	10.51	1.08	.100
For domestic use	31,844,122	40.51	3.89	.384	25,660,305	31.60	3.24	.299
Total coke	47,396,818	60.29	5.80	.572	50,824,229	62.58	6.42	.593
Breeze:								
Used by producer	919,223	1.17	.11	.011	1,268,565	1.56	.16	.015
Sold	744,610	.95	.09	.009	569,161	.70	.07	.006
Total breeze	1,663,833	2.12	.20	.020	1,837,726	2.26	.23	.021
Tar and its derivatives sold	3,743,639	4.76	.46	.045	4,316,686	5.32	.55	.051
Light oil and its derivatives sold	3,545,289	4.51	.43	.043	3,341,922	4.12	.42	.039
Ammonia sold	2,124,999	2.70	.26	.026	2,407,873	2.97	.30	.028
Surplus gas:								
Used by producer	616,920	.79	.07	.007	975,520	1.20	.13	.011
Sold as city gas	18,595,593	23.65	2.27	.224	15,968,382	19.66	2.02	.187
Sold for industrial use	863,584	1.10	.11	.011	1,289,750	1.59	.16	.015
Total gas	20,076,097	25.54	2.45	.242	18,233,652	22.45	2.31	.213
All other products sold, including naphthalene	63,741	.08	.01	-	241,812	.30	.03	.003
Total gross value, all products	78,614,416	100.00	9.61	.948	81,203,900	100.00	10.26	.948
Cost of coal	48,563,832	61.77	5.94	.585	48,474,232	59.69	6.13	.566

	1944				1948			
Coke:								
Used by producer	$8,561,311	6.95	$0.84	$0.085	$9,454,860	5.13	$1.00	$0.106
Sold:								
For blast furnace use	12,363,616	10.04	1.21	.123	21,494,123	11.67	2.27	.241
For foundry use	14,002,345	11.37	1.37	.140	35,096,608	19.05	3.71	.394
For other industrial use	19,847,813	16.12	1.95	.198	42,580,953	23.12	4.52	.478
For domestic use	29,927,953	24.30	2.93	.299	25,982,523	14.11	2.75	.292
Total coke	84,703,038	68.78	8.30	.845	134,609,067	73.08	14.25	1.511
Breeze:								
Used by producer	1,505,849	1.22	.15	.015	2,010,285	1.09	.21	.023
Sold	740,812	.60	.07	.007	957,411	.52	.10	.011
Total breeze	2,246,661	1.82	.22	.022	2,967,696	1.61	.31	.034
Tar and its derivatives sold	5,670,123	4.60	.55	.058	9,030,110	4.90	.96	.101
Light oil and its derivatives sold	5,985,328	4.86	.59	.060	4,737,926	2.57	.50	.053
Ammonia sold	3,013,209	2.45	.30	.030	3,726,228	2.02	.39	.042
Surplus gas:								
Used by producer	1,790,984	1.46	.17	.018	1,371,812	.75	.14	.016
Sold as city gas	17,221,914	13.98	1.69	.172	24,650,951	13.38	2.61	.276
Sold for industrial use	1,708,100	1.39	.17	.017	2,448,762	1.33	.26	.027
Total gas	20,720,998	16.83	2.03	.207	28,471,525	15.46	3.01	.319
All other products sold, including naphthalene	815,076	.66	.08	.008	665,615	.36	.07	.007
Total gross value, all products	123,154,433	100.00	12.07	1.230	184,208,167	100.00	19.49	2.067
Cost of coal	76,093,607	61.79	7.46	.760	109,861,673	59.64	11.62	1.233

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During the past decade, these plants have provided considerable tonnages of coke for metallurgical and other industrial purposes to meet increasing requirements of such fuel. In 1934, when steel production was low and metallurgical-coke requirements were comparatively small, merchant plants and gas utilities marketed the bulk of their coke production for residential and commercial heating, which will be termed "domestic" in the following discussion. In that year gas utilities supplied less than 1 percent of the total blast-furnace coke consumed, 8 percent of the foundry coke, 31 percent of the coke classified as "other industrial" (including coke used in water-gas manufacture), and 20 percent of the domestic coke. Merchant plants furnished 4 percent of the blast-furnace coke, 61 percent of the foundry, 47 percent of other industrial, and 51 percent of domestic. Beginning with the defense program and later in World War II, metallurgical-coke requirements rose rapidly and, as a result, supplies of this fuel from slot-type ovens operated by integrated iron and steel companies were not sufficient to keep pace with the increasing demand. It became necessary to rehabilitate old beehive coke ovens, and merchant and gas-utility plants began to divert coke from the domestic trade to metallurgical plants. For example, gas utilities, which shipped only 8 percent of their total coke sales to blast furnaces and foundries in 1934, were selling 24 percent of their coke to blast furnaces and foundries in 1944, and in 1948 the quantity of coke sold for metallurgical purposes represented 52 percent of the total shipments. The tonnage of coke sold for domestic heating, which accounted for 79 percent of their total deliveries in 1934, dropped to but 34 percent in 1948. The shift was even greater for the merchant coke plants, which cut back their domestic coke shipments from 71 percent of their total sales in 1934 to 37 percent in 1944 and dropped further to 22 percent in 1948. Sales for metallurgical purposes increased from 16 percent in 1934 to 34 percent in 1944 and 41 percent in 1948.

Although iron and steel companies have been engaged in a tremendous coke-oven building program since the early 1940's, blast-furnace capacity also has grown, and their coking capacity has not increased sufficiently to supply metallurgical coke for maximum blast-furnace operations. For this reason it has been necessary to draw coke from beehive, merchant, and gas-utility coke plants to meet iron blast-furnace coke requirements. The quantities and percentages of blast-furnace coke shipped to iron.furnaces are shown in table 5.

TABLE 5. - Sources of blast-furnace coke shipments in 1948

Source	Net tons	Percent of total
Oven coke plants:		
Gas utility.....	547,698	1
Merchant.....	1,620,734	3
Furnace.....	51,784,911	87
Beehive coke plants.....	5,332,163	9
	59,285,506	100

The foundry-coke trade depends greatly on the merchant and gas-utility plants for its metallurgical fuel. The importance of these plants to foundries is shown in table 6.

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TABLE 6. - Sources of foundry-coke shipments in 1948

Source	Net tons	Percent of total
Oven coke plants:		
Gas utility	719,233	19
Merchant	1,859,136	50
Furnace	675,538	18
Beehive coke plants	496,752	13
	3,750,659	100

As shown above, 2,578,369 tons, or nearly 70 percent, of all foundry coke consumed in 1948 originated at plants operated by merchant and gas-utility companies. Of this total, nearly 600,000 tons was supplied by plants expected to close because of the substitution of natural gas. In addition, it should be noted that nearly 50 percent of the foundry coke shown as originating at furnace plants is made by companies that produce pig iron for gray-iron and malleable foundries and nonintegrated steel plants. Several such plants indicated that loss of their city gas contracts will force them to curtail their coking operations, thereby cutting down their foundry coke output.

Merchant and gas-utility plants supply most of the coke used for miscellaneous industrial purposes (gas making, chemical processes, nonferrous smelting, etc.) and classified by the Bureau of Mines as "other industrial." The increase in coke consumed for these industrial purposes has been met largely at the expense of the domestic coke trade. In 1948 merchant and gas-utility plants together furnished 76 percent of all coke used for miscellaneous industrial purposes, whereas iron and steel oven coke plants supplied 15 percent and the balance was obtained from beehive ovens. Ovens expected to close supplied about 400,000 tons, or 5 percent, of the total. Table 7 shows the size of the market of coke for miscellaneous industrial purposes and the proportions supplied by merchant and gas-utility plants.

TABLE 7. - Sources of other industrial coke consumed in 1948

Source	Net tons	Percent of total
Oven coke plants:		
Gas utility	1,794,884	23
Merchant	4,125,745	53
Furnace	1,131,072	15
Beehive coke plants	681,681	9
	7,733,382	100

Coke-oven Gas

As shown in figures 1 and 2, gas ranks next to coke in importance. The relative value of gas to coke-plant operators varies according to the type of operation. At coke plants integrated with iron and steel works, the bulk of the surplus gas is consumed within the works and assigned a low value in accordance with established accounting procedure. Gas utilities and, to a large

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extent, the merchant plants, market the largest proportion of their gas production through city mains for residential and commercial use and for which a higher price is realized.

The coke-oven gas distributed by gas utilities comes from three sources. Gas utilities produce part in their own ovens, some is purchased from merchant companies, and a large part is purchased from iron and steel coke plants. The sources of coke-oven gas distributed through city mains, as reported to the Bureau of Mines for the period under review, are shown in table 8.

TABLE 8. - Sources of coke-oven gas distributed by gas utilities, 1934, 1939, 1944, and 1948

Source	1934		1939	
	M cubic feet	Percent of total	M cubic feet	Percent of total
Gas utility.....	50,674,277	35	46,860,834	32
Merchant.....	66,004,924	46	60,681,520	42
Furnace.....	27,628,948	19	37,334,219	26
	144,308,149	100	144,876,573	100
	1944		1948	
Gas utility.....	53,460,225	31	53,453,433	31
Merchant.....	63,153,726	37	57,284,593	34
Furnace.....	53,699,954	32	58,609,888	35
	170,313,905	100	169,347,914	100

In spite of the increase in volume of coke-oven gas distributed by gas utilities during the past decade, the proportion of coke-oven gas distributed to the total manufactured has decreased markedly. This shift is illustrated in table 9, which has been compiled from data shown in table 16, "Gas Facts, 1948," published by the American Gas Association, New York, N. Y. The gain in production of water gas has increased coke requirements for its manufacture, and between 1939 and 1948 it is estimated that the consumption of coke for use as water-gas generator fuel increased nearly a million tons.

TABLE 9. - Comparative percentages of different kinds of manufactured gas distributed by gas utilities, 1934, 1939, 1944, and 1948

Kind of gas	Percent of total			
	1934	1939	1944	1948
Carbureted water gas.....	47	49	55	59
Coke-oven gas.....	42	42	39	35
Retort coal gas.....	9	5	4	2
Oil and oil refinery gas.....	2	4	2	4
	100	100	100	100

Although the supply and distribution of manufactured gas has grown continuously to 1949, it has not paralleled the spectacular increase registered by

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the sales of natural gas. In fact, preliminary data for 1949 indicate that the volume of natural-gas sales by gas utilities increased about 9 percent, whereas sales of manufactured gas declined more than 3 percent from the 1948 totals. The tremendous increase in volume of natural gas distributed by gas utilities is shown in the following table compiled from data published by the American Gas Association, "Gas Facts, 1948," table 71.

TABLE 10. - Public utility gas sales, by types of gas, 1934, 1939, 1944, and 1948

	1935-39 = 100						1945 = 100	
	Natural gas		Manufactured gas		Mixed gas		Liquid petroleum gas	
Year	M cubic feet	Index	M cubic feet	Index	M cubic feet	Index	M cubic feet	Index
1934.....	932,550	78	302,986	102	72,191	84	a/	-
1939.....	1,297,979	109	303,144	103	89,751	105	a/	-
1944.....	2,113,716	177	384,559	130	134,969	157	b/2,716	100
1948.....	2,894,650	242	442,154	150	148,102	172	10,134	373

a/ Not available. b/ 1945 figure.

The contemplated introduction of natural gas to many areas heretofore supplied with coke-oven gas no doubt will accelerate the increase in use of natural gas by utilities, and more coke-oven gas will be displaced. This development is not so important to the plants associated with iron and steel works, as the gas probably can be used in their metallurgical operations. It is very important, however, to certain merchant companies, as they must have a market for their gas, as well as their coke and other products, in order to maintain their economic life. Selection of coal and modification of operating methods permit wide changes in the ratio of gas to coke, or coke to tar, but economic as well as engineering and chemical considerations prevent the extreme application of this idea. For example, at utility plants where a maximum of coke-oven gas is desired for sale, the ovens are heated with a lower B.t.u. gas, such as producer or blue-water gas. This is especially advantageous during periods of peak demand, but when the demand for gas slackens the ovens can be fired with coke-oven gas. This practice is followed less extensively by merchant plants, and some steel companies utilize their blast-furnace gas for firing coke ovens to release their coke-oven gas to integrated steel operations. Table 11 shows the extent to which the coke plants used coke-oven gas for underfiring in 1948.

TABLE 11. - Coke-oven gas used for heating ovens, by kind of plants, in 1948

Kind of plant	Produced (M cubic feet)	Used to heat ovens (M cubic feet)	Percent used to heat ovens
Gas utility.....	60,987	4,604	8
Merchant.....	130,934	40,483	31
Furnace.....	802,931	325,569	41
	994,852	370,656	37

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Coke-oven Tar

Crude tar represents 4 to 5 percent of the weight and 5 to 8 percent of the heat of the original coal from which it is made and ranks third in importance to coke and gas. In recent years it has also ranked third in economic importance, based on income derived from its sale. The principal uses of tar are: (1) as raw material for the manufacture of numerous organic chemicals, (2) as fuel for open-hearth furnaces or other metallurgical operations, and (3) as a fuel under boilers. Processing of crude coal tar is increasing in importance because of the rising demands of the synthetic organic chemicals industry. Unlike the majority of the iron and steel plants, which can burn the tar in their integrated metallurgical operations or sell it to tar refineries according to business and economic conditions, the gas-utility and merchant coke plants must market their production. The principal outlets for their tar are the tar distillers and table 12 shows the quantity and proportion of tar sales to refiners in recent years.

TABLE 12. - Coke-oven tar sold to tar refineries, by kind of plants, 1934, 1939, 1944, and 1948

Year	Sales to refiners (gallons)	Gas utility		Merchant		Furnace	
		Gallons	Percent of total	Gallons	Percent of total	Gallons	Percent of total
1934	236,465,919	51,683,000	22	81,994,534	35	102,788,385	43
1939	278,391,502	40,257,134	14	82,110,109	30	156,024,259	56
1944	391,338,435	48,782,568	12	108,939,425	28	233,616,442	60
1948	367,730,103	45,126,767	12	94,077,524	26	228,525,812	62

Although the proportion supplied by furnace, or iron and steel, plants has been increasing steadily, the quantities supplied by the gas utilities and merchant plants are substantial and accounted for 38 percent of the total quantity of coke-oven tar purchased by tar distillers in 1948. Plants that are expected to close within 10 years supplied about 26,000,000 gallons, or 7 percent of the total. In an emergency this quantity would be very important and could not be replaced quickly.

Coke-oven Crude Light Oil

Crude light oil is an important primary product because of its derivatives, particularly benzene (benzol). The principal chemical grades of benzol (1° and 2° C.), although not used extensively in that form, are the source of such chemicals as aniline, chlorobenzene, phenol, styrene, etc. These parent products may then be changed through many steps to produce substances that constitute the finished dyes, medicinals, plastics, synthetic rubber, certain synthetic fibers, rubber chemicals, etc.

Until recent years, not all of the benzol production was required for chemical use, and the bulk (70 percent in 1934) was used as a motor fuel because of its high octane rating. With the beginning of World War II, however, chemical requirements increased greatly, and the proportion of motor benzol to chemical or industrial grades reversed. Also, during World War II one of the

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largest uses of benzol was for the manufacture of cumene to enrich aviation gasoline. Since the end of the war the increased requirements of chemical grades have absorbed nearly 95 percent of the avialable supply of benzol, and very little has found its way into motor fuel. Coke ovens are the principal source of this important aromatic chemical, although a considerable amount of scientific work has been done to produce benzol commercially from petroleum. Several petroleum companies have already inaugurated production of benzene on a commercial basis from cyclohexane.

Benzol represents about 65 to 70 percent of the volume of the crude light oil from which it is recovered. The production of crude light oil and, of course, benzol depends on coking activity, although it is influenced to a certain extent by the type of coal chosen, coking temperature, and kind of recovery equipment. This is clearly illustrated in table 13.

TABLE 13. - Relative yields of light oil per ton of coal carbonized, by kind of plants, 1934, 1939, 1944, and 1948

Kind of plant	1934	1939	1944	1948
Gas utility.....	1.61	1.47	1.83	1.60
Merchant.....	2.56	2.74	2.72	2.42
Furnace.....	3.14	3.12	2.96	2.85
Average all plants.....	2.90	2.99	2.87	2.73

At some gas-utility plants only part of the light oil is recovered from the gas resulting in the low yield per ton of coal carbonized. In fact, three plants did not recover any light oil in 1948 in order to increase the B.t.u. of gas distributed to residential and commercial consumers. Unlike the merchant and furnace coke plant operators who refine nearly all of the light oil produced by them, gas-utility coke plants sell more than a third of their product to tar refineries, as shown in table 14.

TABLE 14. - Coke-oven crude light oil produced and refined on premises, by kind of plants, 1934, 1939, 1944, and 1948, in gallons[a/]

Kind of plant	1934			1939		
	Produced	Refined	Percent refined	Produced	Refined	Percent refined
Gas utility..	4,106,510	1,013,606	25	3,684,136	708,733	19
Merchant.....	25,669,724	23,238,011	91	26,595,829	25,196,758	95
Furnace.....	85,918,514	83,967,847	98	140,683,234	138,041,676	98
	115,694,748	108,219,464	94	170,963,199	163,947,167	96
	1944			1948		
Gas utility..	8,721,650	4,109,503	47	8,217,029	5,295,571	64
Merchant.....	38,180,257	41,962,551	110	26,688,265	24,623,300	92
Furnace.....	220,960,077	211,972,478	96	221,183,771	213,037,345	96
	267,861,984	258,044,532	96	256,089,065	242,956,216	95

a/ At merchant plants, purchased crude light oil is refined in addition to their own production.

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TABLE 15. - Production of benzol (all grades), by kind of plants, 1934, 1939, 1944, and 1948

Kind of plant	1934 Gallons	1934 Percent of total	1939 Gallons	1939 Percent of total
Gas utility.....	506,000	1	282,303	1
Merchant.....	14,442,572	20	15,063,978	14
Furnace.....	56,788,917	79	89,566,583	85
	71,737,489	100	104,912,864	100
	1944		1948	
Gas utility.....	2,456,112	1	2,917,880	2
Merchant.....	25,749,512	16	14,919,686	9
Furnace.....	137,260,814	83	141,175,652	89
	165,466,438	100	159,013,218	100

These figures show that merchant and gas-utility coke plants supplied 17,837,566 gallons, or 11 percent of the total, in 1948. The direct loss in annual benzol production due to closing of plants within the next 10 years because of the introduction of natural gas and old oven failures may total about 3,600,000 gallons. However, as several plants sell their output of light oil to other concerns for processing, the total loss in benzol output may amount to about 4,800,000 gallons per year.

Coke-oven Ammonia

Coke-oven ammonia is recovered at coke plants, either as a water solution (ammonia liquor) or as crystallized ammonium sulfate. For the entire coke industry the proportion of ammonia converted to ammonium sulfate approximates 90 percent of the total. The merchant coke plants, however, recover a larger proportion of the ammonia in the form of ammonia liquor. For example, in 1948, of the 29,613 tons of ammonia (NH_3 equivalent of all forms) produced at merchant plants, 52 percent was recovered in the form of ammonia liquor. Sources of ammonia liquor produced in the coke industry are shown in table 16.

TABLE 16. - Production of ammonia liquor, by kind of plants, 1934, 1939, 1944, and 1948

Kind of plant	1934 Net tons	1934 Percent of total	1939 Net tons	1939 Percent of total	1944 Net tons	1944 Percent of total	1948 Net tons	1948 Percent of total
Gas utility..	1,902	9	1,585	7	2,581	8	1,058	4
Merchant.....	15,537	71	14,546	60	16,408	52	15,252	62
Furnace.....	4,358	20	8,001	33	12,676	40	8,443	34
	21,797	100	24,132	100	31,665	100	24,753	100

The ammonia liquor produced by coke-plant operators is used for both chemical and agricultural purposes. Although precise data are not available on the quantities of ammonia liquor used for each category, it is estimated that more

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than half is used industrially for the manufacture of soda ash, ammonium chloride, and sulfuric acid. The balance is used by the fertilizer industry for agricultural purposes.

Until recent years coke ovens furnished the bulk of the ammonium sulfate consumed in the United States. Virtually all of the sulfate production is used as a fertilizer material. However, in the past several years, a few of the large synthetic-ammonia producers have constructed plants to produce ammonium sulfate, and the proportion of ammonium sulfate supplied by this source has increased markedly, as shown in table 17.

TABLE 17. - Sources of ammonium sulfate produced in the United States, 1934, 1939, 1948, and 1949

Source	1934		1939	
	Net tons	Percent of total	Net tons	Percent of total
Coke oven.....	392,722	100	580,274	100
Synthetic[a].....	[b]	-	[b]	-
	392,722	100	580,274	100
	1948		1949[c]	
Coke oven.....	830,681	76	757,759	47
Synthetic[a].....	264,476	24	846,694	53
	1,095,157	100	1,604,453	100

[a] Bureau of the Census. [b] Not available. [c] Preliminary.

The sources of coke-oven sulfate are shown according to kind of plants in table 18.

TABLE 18. - Production of coke-oven ammonium sulfate, by kind of plants, 1934, 1939, 1944, and 1948

Kind of plant	1934		1939	
	Net tons	Percent of total	Net tons	Percent of total
Gas utility.....	37,872	10	40,784	7
Merchant.....	59,570	15	61,014	11
Furnace.....	295,280	75	478,476	82
	392,722	100	580,274	100
	1944		1948	
Gas utility.....	40,133	5	40,129	5
Merchant.....	69,370	8	57,445	7
Furnace.....	708,740	87	733,107	88
	818,243	100	830,681	100

Interior - Bureau of Mines, Pittsburgh, Pa.

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